STRUCTURES NORTH
CONSULTING ENGINEERS, INC.

30 June 2006

Massachusetts Department of Conservation and Recreation
251 Causeway Street
Boston, MA 02114
Fax: 617-626-1349

Attention: Mr. Jeffrey Harris

Reference: Richardson Park Flagpole

Dear Jeffrey:

On Wednesday, 31 May 2006 we performed a structural investigation of the Richardson Park flagpole via aerial lift. This included a tactile visual inspection, field measurement of geometry and defects, and Resistograph test-drilling. The following is a summary of our findings and recommendations.

General Description

The Richardson Park flagpole is a composed of a single solid Douglas Fir timber that is 23" in diameter at the base and linearly tapers to 11" diameter at the top and then 8" diameter at the crown. Historical records obtained by the DCR have the flagpole being erected "as a lasting tribute to the youth of Dorchester, as well as veterans" in June of 1935, with a total length of 110-feet. Our own approximate check by GPS puts the height above grade at around 100-feet and the typical depth below grade is approximately 10% of the height, or in this case ten feet.

The base of the flagpole is set into the ground within a concrete capped caisson.

Rigging consists of a single looped rope halyard that is run through a block at the top of the pole and fastened to a cleat that is approximately ten feet above the ground. There are two bolt-snaps on the halyard, one for the top and one for the bottom corner of the flag. The bottom bolt-snap hangs from the tethered rope below the cleat. The upper clip is on the taut part of the halyard, approximately fifteen to twenty feet above the cleat.

At the top of the flagpole was a metal ball finial. This was supported by a rod that was bolted into an extended knob at the top of the pole, about which it was turned.

For the purposes of this report, we will refer to a specific "face" of the pole and a directional orientation. While a round structure clearly does not have any real "faces", this will technically refer to the nearly vertical surface of a 45-degree arc that is centered about the referenced compass direction. "Depth" will refer to the horizontal radial distance that a condition penetrates from the outer surface of the pole toward the center.

Noted Conditions

Materially, the core of the flagpole is in sound condition and the wood grain is dense and generally free of knots and checks (radial shrinkage cracks). At the outer fibers, however, the flagpole has been weakened by rot, insect and surface chafing, as well as damage caused by a lightning strike (*please see photo1 at the end of this report*).

Lightning Damage-

When lightning strikes the earth it does so by sending out successive "stepped ladder" strokes of limited length and intensity that work their way downward from the sky. When these reach to within 10 to 100 yards of the ground or a grounding element, it is met with a much more powerful "return" stroke that comes up from the ground, traveling via the path of least resistance (a life-threatening experience while camping in the mountains personally demonstrated this reality). This can often be a conductive or semi-conductive structure, such as in our case a flagpole, or preferably, a lightning grounding rod ("lightning rod") which is designed to transmit the return stroke's electrical current with the least amount of energy dissipation.

Wooden elements typically contain varying amounts of moisture within their pores, in addition to air. When large electrical currents are forced through wood, they tend to travel through the most moistened paths, since water is a much better conductor than air or even wood fiber. Because there is still considerable resistance to current passing through moist wood, energy is lost through transmission in the way of heat. Lightning's very short, very high burst of current results in a very sudden and intense generation of heat, that immediately turns the entrapped moisture into steam. This steam is formed so rapidly that it has no other way to escape from the wood matrix other than to explode outward, binging the entrapping wood with it. In thinner wood elements with damp cores, this explosion can split the elements down the middle or zigzag its way downward breaking the element into several pieces. In thicker elements, usually with a drier core, lightning will form trenches along its path of travel, where the explosions are limited to only the wood that is on the outside of the path, leaving the core intact.

At Richardson Park, the flagpole is of sufficient breadth that the latter occurred, leaving vertically oriented trenches running from the top of the flagpole almost to the ground. Except where the wood is rotted, inner surfaces of the trenches follow common growth rings where shakes (growth ring delaminations) have occurred leaving almost smooth surfaces. The edges of the trenches are sometimes almost radial in orientation, having occurred along checks (radial cracks) that either pre-existed or occurred during the strike.

At the very top of the flagpole, the original ball finial and anchorage was blown off of the pole by the lightning strike (*photos 2 and 3*). This is assumed to be the point at which lightning entered the pole.

Starting from almost the top as a deep, intermittent check (*photo 4*) , a trench runs down the north face, increasing in depth to a maximum loss of 3 inches near the mid-height of the pole and continuing downward to almost nothing at the very bottom of the pole (*photos 5 and 5*). Much of the inner surface of this trench follows delaminated planes of growth rings, which extend beyond the edges of the trench in the form of shakes (*photo 7*).

At the south face, there is a 1½" trench that starts at about the ten-foot elevation and runs almost to the bottom, crossing several areas of rot-pocketed wood on its way.

Chafing Damage-

At two locations, one near the mid-height of the pole and one near the base, the surface has been deeply chafed by the bolt snaps blowing and knocking against the wooden surface. These correspond to positions at which the snaps have been furled for extended periods of time. The upper location has been painted since the last time it was chafed (*photo 8*) and the lower location lies against a rot pocket and has chafed more than two inches into the pole (*photos 9 and 10*).

Rot and Insect Damage-

There is limited weakening from rot at the very top of the pole, where the balled finial once was attached. The end grain has been hollowed out at the center due to the upward exposure of end grain and the possiblility that water would collect on it (*photos 2 and 3*). This is limited in extent and within less than a foot the core of the flagpole is sound.

Rotted "pockets" have formed along the south and east faces of the flagpole, running from a height of about five feet above the base at the southeast face to approximately ten feet from the top of the pole. According to the Resistograph, these have a maximum depth of five inches into the pole at the south and east faces, at about 30 feet from the base, and again at the south face about 70 feet from the base. This rot is basically a cubical brown rot (*photos 11*) that eats the cellulose and hemicellulose from the wood's fiber structure leaving only the lignin. At full maturity, brown rot eliminates all tensile capacity from the affected wood fibers, causing it to break into a cubic form, reminiscent of wood that has been extensively charred in a fire but without the black color, and then turning it almost into a loamy soil. Much of the rotted pockets are filled with rotted material, which has been made stable by the many coats of paint upon the surface. The rot is only externally visible where the surface has been disturbed by the lightning strike or where we have removed material to expose the internal conditions (*photos 12 and 13*).

Further down on the flagpole, the rot is accompanied by carpenter ants (some of which we saw during our investigation) that have tunneled into the damp rotted material as well as the dampened wood directly adjacent to it (*photos 14 through 16*).

The base of the flagpole is set into the ground with a metal-flashed concrete slab on grade that encircles it. Whether the base is embedded in concrete, or crushed stone or sand encased in a concrete caisson is not known, however as is commonly the case, perennially damp or wet conditions exist, as is evident through examination of the wood fibers at the edge of the cap slab.

There is a partial ring-like pocket of rotten and insect-eaten wood where the south face of the pole meets the slab. This has a maximum penetration of 1½", according to the resistance drill, and reduces to as little as ½" at the other faces of the pole (*photos 17 and 18*). One of the main concerns that we have regarding this rot at the flagpole base is that it may be an indicator of more severe conditions below. Constantly damp conditions would normally promote rot and wood-boring insects in attacking the pole, unless conditions are so wet that no oxygen can reach the wood fibers and no rot or insects could survive, which is in our opinion unlikely except under very controlled, and sealed conditions. Also, what happens where the anaerobic, saturated wood meets the atmospheric, non-saturated wood- one would at least expect there to be some rot or insect activity within some transition zone between constantly wet and mostly dry. There is unfortunately no way of determining the hidden condition of the embedded wood, other than to excavate into the caisson or to pluck the pole out of the ground.

Structural Analysis

We performed a structural analysis of the flagpole using the "Guide Specifications for Design of Metal Flagpoles" published by the National Association of Architectural Metal Manufacturers as ANSI/NAAMM FP 1001-97. The load calculation portion of this standard is appropriate for flagpoles of any material since external loads are independent of the materials on which they are applied. In according to the standard, we considered a flagpole height of 100-feet, diameters as measured in the field, and a 20-foot by 30-foot nylon, cotton or polyester flag at the top of the pole. Based upon the geographical location of the pole, we considered a wind speed of 110 miles per hour. Based upon these assumptions, we calculated the bending moments at the base and mid-height of the pole, both with the flag and without.

We determined by microscopy that the flagpole's wood species is Douglas fir, noting the obvious spiral thickenings in the longitudinal cells that are an unmistakable identifier of the species. We visually confirmed that the grade of wood satisfied the equivalent of ASTM Standard D3200. Based upon this standard, and all referenced modifiers, a Douglas fir pole of the given diameter would have allowable bending stresses of 3,056 pounds per square inch (psi) at the base and 3,154 psi at mid-height under wind loading conditions.

If the flagpole had no defects or damage and its entire cross-section were effective for its entire length, the calculated bending stresses under full wind load with flag would be 2,673 psi at its base and 1,768 psi at mid height. These are less than 3,056 psi and 3,154 psi respectively, that demonstrates that the pole as originally built would meet today's standards.

Considering actual conditions at the base, it would be a reasonable approximation to assume an average loss of one inch of material for the entire circumference. This would result in a full wind bending stress of 3,508 psi with the flag and 2,886 psi without it, or 22% overstressed with the flag and within allowable limits without it.

At mid-height, if we consider a loss of two inches of depth by eight inches of width on each face (approximating the measured loss from lighting on one face and the loss from rot on the other at that elevation), there would be full wind bending stresses of 2,695 psi with the flag and 1,901 psi without it, both of which are within allowable limits.

At the approximate point of one quarter height, the combined losses from rot and lightning damage are at their greatest. Here we estimate that the full wind bending stresses are 5,656 psi with the flag and 4,483 psi without it.

The Bending stress with and without the flag exceed the allowable by an alarming 79 and 41 percent, respectively.

Remedial Options

There are two basic options for restoring an operating flagpole to this site: repair and replacement.

Repair for 90-foot Height (90-extension above grade)-

Repairing the flagpole would consist of removing the flagpole from its base, either by cutting or plucking it out. From flagpole-experienced contractors that I spoke with, the possibility of easily plucking the flagpole from its base is slim due to the fact that it is probably wedged tightly into position by years of vibrating and tamping of the packing materials that restrain the base of the pole. Also, given the rot that is visible just above the ground surface, it is likely that the buried portion of the pole is rotted and/or insect damaged, and would not be re-useable, especially for re-burial after repairs.

After cutting off and lowering, the foreshortened flagpole would be transported to a location where it could be examined and repaired under climate-controlled conditions.

All rotted and insect damaged wood should be removed along with all wood that has been exploded away from the core by lightning but has not fallen off of the pole. Permanent repairs would consist of matching timber dutchmen (fitted pieces) that would be mechanically fastened and glued into place. Ideally, a tight fit and proper cleaning, honing and drying of both the dutchmen and the substrate would be would need to be achieved, along with both the new and existing wood needing to be installed at the same moisture content.

While contractors with whom I consulted were optimistic about the practicality and longevity of this approach, it is our opinion that it is debatable whether truly permanent structural timber repairs could be made to the pole that would last indefinitely through countless moisture and temperature cycles, in an exposure that is frequently buffeted by wind and exposed to rain, ice, sleet and snow. Because of the elements, the very high bending stresses involved and the magnifying effect that the very large diameter of the pole would have on seasonal shrinkage and expansion movements, as well as the difficulty of frequent inspection and frequent maintenance, we would not practically expect the repairs to last more than 15 to 20 years. After that time, the repairs would likely need to be reapplied or the pole removed.

The estimated cost for repair of the remaining 100-foot long (90-foot extended) flagpole, including removal, transportation, shop rental, cleaning, painting, all wood repairs as described above, new halyards, updated hardware with a new gold leafed ball finial and lightning protection, and re-erection into a new base would be $90,000 to $100,000, with an assumed service life of 15 to 20 years.

Repair for Half-Height (50-foot extension above grade)-

An alternative long-term approach would be to foreshorten the pole until such a height that the reduced cross-section (not counting on the repairs for strength) would be sufficient. The repairs would then be considered weather-protective, non-structural patches while the parent material would be heavily treated with preservatives. We estimate that as much as 40- to 50- feet would need to be removed from the overall length of the pole (including the embedded base) for this to be achieved.

The estimated cost for repair of the foreshortened 50- to 60-foot long flagpole, including removal, transportation, shop rental, cleaning, painting, all wood repairs as described above, new halyards, updated hardware with a new gold leafed ball finial and lightning protection, and re-erection into a new base would be $50,000 to $60,000, with an assumed heavy-maintenance cycle of 15 to 20 years but an extended service life beyond that.

Full-Height Replacement (100-foot extension above grade)-

The obvious alternative to repairing the pole is replacing it. Material options include painted steel, brushed aluminum and fiberglass, while wood is unfortunately not an option with today's scarcity of long high-grade old-growth timbers. Painted steel rusts and requires maintenance, while brushed aluminum would create a modern look that would most likely be rejected by the community. Fiberglass is, in our opinion, the most appropriate of the three materials.

According to the High Flying Flag Company of Greenland, NH, a "PLP-1001" fiberglass pole would have an above-ground height of 100-feet, below-grade embedment of 10-feet, a butt (base) diameter of 17 ½" and a top diameter of 7". These dimensions are actually less than the present wood flagpole, resulting in a more slender appearance. The standard rating of the pole is for a 15-foot by 25-foot flag, however, I was told by the High Flying Flag that a 20-foot by 30- foot flag could safely be used.

There would be an access door at the base of the pole to access an internal wire halyard with a crank for hoisting and lowering the flag. There would be a revolving aluminum truck with an aluminum ball with a gold finish. The pole would be virtually maintenance-free other than for the replacement halyards and snap hooks at about every two to five years. Exterior finish on the flagpole would be a semi-glossy white finish that would fade to a dull white after approximately ten to fifteen years. Structurally, the flagpole itself can be assumed to last more than 30-years, based upon similar installations that have been in service for this amount of time.

The estimated cost for a new -foot long flagpole, including removal and disposal of the old one, transportation, hardware as described above, lightning protection and re-erection into a new base would be <u>$40,000 to $50,000</u>, with the assumption that the pole itself would last indefinitely.

Base Installation-

Included in the above estimates is a new base that would consist of a ten-foot deep cast-in-place concrete sleeve supported on a concrete footing with drain holes. The flagpole would be inserted into the sleeve and the annular space around it would be filled with sand. The sleeve would then be capped with a concrete slab apron and the joint between the pole and the slab would be sealed with a flashing and skirt. This would be located in close proximity to the original installation, topsoil and sod would be removed from the new installation and stockpiled for relocation.

The old base would have the slab demolished, the flashing removed, and the wooden pole cut to be even with the former bottom of the slab (and top of the remaining sleeve, if any). The existing topsoil and sod would then be relocated to cover what is left of the former one. This has also been included in the above estimates.

Conclusions and Recommendations

Cost Considerations-

If we look at life-cyle costs, the repairing 100-foot length of flagpole has the highest annualized cost at $3,000 per year of service plus a moderate-to-high maintenance cost.

Repairing the shortened length has an annualized cost of $2,000 per year assuming a 30-year service life plus a high maintenance cost if one assumes that the Dutchmen will need to be partially replaced or reinforced after 15- to 20-years.

Replacement with fiberglass has the lowest annualized cost at $1,666 per year with a 30-year minimum service life and low maintenance costs, making this by far the most cost-effective option.

Aesthetic Considerations-

Aesthetically, the most attractive option would be to preserve and repair the existing flagpole as long as it is well-maintained.

Fiberglass is the second most aesthetically attractive option unless the existing flagpole is not well-maintained and paint begins to peel, metal rusts and wood begins to rot, whereas then a fiberglass flagpole would look better than a poorly maintained wooden one.

The foreshortened flagpole would be the least attractive, aesthetically, as the pole's present high visibility would be lost.

Historical Considerations-

Regarding the retention of historic fabric, the greatest amount of historic fabric would be preserved under the 90-foot repair option. The loss of ten feet in height and its on-site relocation would detract from the pole's historical integrity, however, this could be noted in a plaque located at the pole's base. The Dutchman repairs would not, in our opinion, detract from the overall historical integrity as these are appropriate repairs for historic elements represent a concerted effort to save the original fabric.

Cutting the flagpole down to half of its length would essentially "archive" a portion of the original wood material on the site, but would represent such a vast physical and dimensional change that virtually all historical integrity would be lost.

Replacement with a new fiberglass pole would retain the "socio-historical" integrity (meaning that a pole of equivalent size would remain on the site) but would be a total loss in fabric.

Functional Considerations-

The fiberglass pole, with its crank-operated internal halyards, would be the easiest to maintain and to use, while the 90-foot high wooden pole would be the most difficult.

The shortened pole would be easier than the longer one to operated, but would not support a flag of the 20-foot by 30-foot size that is presently used.

Recommendation-

Given the above discussion, all but the Historical Considerations suggest that replacement with a fiberglass pole would be as good if not better than the restoring the present wood one. With this in mind, as well as the difficulty and *expense of maintaining a tall structure at the site, and the potential threat to safety if either of the restored options is not properly maintained, continues to insidiously rot and eventually falls over, we recommend that the existing pole be replaced with a fiberglass one.*

We trust that the preceding information will be helpful in understanding the structural condition and intervention needs of Richardson Park flagpole. Please contact us if you have any questions or comments.

Respectfully yours,

John M. Wathne, PE, President
Structures North Consulting Engineers, Inc.